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ABSTRACT

This paper has two major objectives. The first is to examine a broad "umbrella" goal for school science programs, commonly referred to as "scientific literacy," which has evolved in practice as a way to express a balanced formulation of the several legitimate and competing purposes for teaching science in schools. The second is to argue in favor of such a balance when goals for science education are being formulated and decided upon. Several areas are discussed as they relate to these two objectives. These include an examination of science curriculum content and intent (what students learn and why it is learned), seven curriculum emphases for science education (everyday coping, structure of science, science/technology/decisions, scientific skill development, correct explanations, self use explainer, and solid foundations), and how these curriculum emphases get into science programs. Other areas addressed include the logic of educational slogans and the diversity of interpretations given to "scientific literacy" between about 1960 and about 1980. Three suggestions concerning the curriculum policy debate, from the perspective of scientific literacy, are also discussed, (including problems of implementing policy changes). (JN)

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Scientific Literacy

Towards Balance In Setting Goals for School Science Programs

A Discussion Paper
by Douglas A. Roberts



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SCIENTIFIC LITERACY
Towards Balance in Setting Goals
for School Science Programs

A Discussion Paper
by Douglas A. Roberts

April 1983

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FOREWORD

This paper is the sixth in a series of discussion papers prepared for a study of Canadian science education being undertaken by the Science Council of Canada, under the direction of its Science and Education Committee. The study, which began in the spring of 1980, has three overall aims:

- . to establish a documented basis for describing the present purposes and general characteristics of science teaching in Canadian schools;
- . to conduct an historical analysis of science education in Canada;
- . to stimulate active deliberation concerning future options for science education.

As this third aim suggests, the Science Council has, at present, no collective view on desirable directions for science education in Canada. However, in order to develop such a view, it is actively soliciting a diversity of opinions. It is intended that these viewpoints, expressed in the form of discussion papers and disseminated as widely as possible, will prompt science educators and others to review current policies and practices. By sharing in these deliberations and at the same time conducting a systematic inquiry into current and past policies and practices, the Science Council hopes to acquire a good understanding of the state and needs of science education in this country, and thereby make constructive recommendations.

Earlier papers in the series have each selected a particular feature of the "educated person" and have argued from this feature that science education in school ought to emphasize a specific group of objectives. These selected features have also given the authors bases from which to criticize present policies and practices in science education. For example, James E. Page focussed on the lack of a Canadian context in science education, Glen Aikenhead on its failure to deal with the social implications of science, Donald A. George on the lack of attention to the skills of an engineer, Hugh Munby on the tendency for students to become intellectually dependent on teachers and textbooks, and Marcel Risi on the inadequacy of teaching science as only a body of knowledge.

This paper takes an entirely different approach; it asks how all of these valid criticisms can be responded to in the context of a real science program. In answering this question, Douglas A. Roberts - himself, a member of Council's committee on science and education - reconstructs the concept of "scientific literacy" as representing a balance among a variety of otherwise competing purposes for teaching and learning science.

It must be stressed that the views expressed in this discussion paper are those of the author, and not necessarily those of the Science Council or its Science and Education Committee. However, in publishing the paper, Council believes that a well-argued position has been set out, and that discussion amongst a wider audience can benefit both the study and Canadian science education in general.

James M. Gilmour,
Director of Research,
Science Council of Canada.

I INTRODUCTION

During the past two years, the Science and Education Study being conducted by the Science Council of Canada has published five "discussion papers" designed to stimulate debate about the goals of school science programs in Canadian provinces and territories. The authors have elaborated convincing reasons for reorienting school science programs in five different directions, arguing in turn for:

- . more Canadian content (Page¹);
- . more attention to science/society issues (Aikenhead²);
- . more attention to the engineering and technological applications of science (George³);
- . programs to help learners understand scientific thinking well enough that they can appraise it with intellectual independence (Munby⁴);
- . more attention to holistic and creative applications of science in problem solving (Risi⁵).

To any teacher or curriculum worker these are apparently conflicting demands, yet all of them make good sense. In the practical world of curriculum making and science teaching, can all of these important matters be accommodated? The answer is "Yes." The further question is "How?"

I have two purposes in this paper. The first is to examine a broad "umbrella" goal for school science programs, commonly referred to as "scientific literacy," which has evolved in practice as a way to express a

balanced formulation of the several legitimate and competing purposes for teaching science in the schools. The second is to argue in favour of such a balance when goals for science education are being formulated and decided upon. To fulfill these two purposes, the story line of this paper proceeds through four major points.

(1) It is impossible to teach science content without simultaneously expressing curricular intent, or purpose. That is, what a student is learning (say, kinetic-molecular theory) is only half the curriculum. Why it is to be learned (say, in order to understand how models are developed in science to explain natural phenomena), which the student also learns, is the other half. That second half, which can be called the "curriculum emphasis" of any part of the science program, is what varies in the five discussion papers noted earlier. The subject matter of science courses is not necessarily at issue.

(2) Seven distinct curriculum emphases can be detected in the history of science education in North America. Each of these embodies an answer to the question "Why should students learn science?" The selection of an answer to that question is a sociopolitical process of deliberation. The answer will legitimately differ for different students and for different regions of a country such as Canada. There is no "scientific" or "theoretical" or "correct" answer to the question, but there will be a "best" (or most defensible) answer for any given unique situation.

(3) The phrase "scientific literacy" is used frequently to mean comprehensiveness in the goals of a science program, and therefore balance among the several competing curriculum emphases. However, the phrase did not begin its linguistic life that way. It therefore has retained some different meanings which it acquired during the evolution of its use in the profession.

(4) Each of the seven curriculum emphases for science education, like each of the five discussion papers, has a reasonable basis. None is

inherently superior to the others. Therefore, every student should be exposed at some point to all possible curriculum emphases, even though more intense concentration on some emphases will be more appropriate for some students.

II CURRICULUM EMPHASES: OBJECTS OF CHOICE

"Why Are We Learning This Stuff?"

Formulating a satisfactory answer to that student query frequently causes science teachers a great deal of discomfort. Yet, students do ask the question, and thereby remind us that teaching has two components: content and intent (or purpose). To illustrate the point and its significance, let us use that ancient and venerable teaching device, the textbook.

Consider two science textbooks, written for students in grade nine, that deal with the topic of heat. Both deal with basic principles that summarize a scientific understanding and explanation of thermal phenomena - such familiar items as the three means by which heat travels, the basic points of kinetic-molecular theory and the difference between heat and temperature. Yet the one text embeds that subject matter in a series of discussions about the ways in which these principles are applied in the technology of everyday life, explaining, for example, the workings of convection currents in hot water heaters and the differential expansion of bimetallic strips used in thermostats; the other embeds the same subject matter in a story line showing that caloric theory has been replaced by kinetic-molecular theory in the development of physics. The first text teaches the student that the purpose of learning the science is to be able to understand familiar everyday gadgets. The second gets across the message that one learns science in order to understand the scientific enterprise itself.¹

Whenever one finds two textbooks that treat the same subject matter yet have a distinctly different "flavour," one can be sure it is the curriculum emphasis, or purpose for learning the material, which is responsible for the difference. The same is true of teaching, and of curriculum guidelines and resource documents. Content and intent, by the very nature of education, are always present. (It is worth noting that science textbooks which seem to present nothing but "straight content" also teach the student a message about the intent of learning: "Learn 'the stuff' for its own sake.")

Now, the five discussion papers released by the Science and Education Study focus on five different purposes for learning science. Each author argues, convincingly in my judgement, that adequate treatment of his particular purpose for learning science should be an important part of the school science program. Some of the authors, indeed, argue that the purpose they are discussing is completely ignored in Canadian school science. How do different purposes for learning science get included in, or excluded from, the science program?

Seven Curriculum Emphases for Science Education

The purpose for which a student is meant to learn science, or any other subject, we can conveniently call the "curriculum emphasis" of the program, or portion of the program, under examination. Seven of these can be found in the history of science education practice in elementary and secondary schools in North America. Their names are suggestive of their meanings; nevertheless, a few comments are presented about each for further clarification.²

An Everyday Coping emphasis orients science teaching towards the application of science to objects and events of fairly obvious importance to the student. Topics in biology, for instance, can be organized and taught so that the students' purpose in learning them is to understand the functioning and intelligent care of the human body. Chemistry topics can be taught in the service of understanding certain common chemical processes

which occur in the home, the automobile and industry. Physics topics can be oriented to show how various common home devices - such as the telephone, the furnace or the electric iron - function and can be maintained.

A Structure of Science emphasis orients teaching in such a way that the student comes to understand how science functions as an intellectual enterprise. Attention is given to the relationship between evidence and theory, the adequacy of any given model to explain the phenomena at hand, the self-correcting features of the growth of science, and similar matters relating to the way in which scientific knowledge is developed. This is a very common emphasis in science education worldwide at this time.

A Science, Technology and Decisions emphasis draws attention to the limitations of science, but also to its strengths, in dealing with the practical affairs of mankind. Science is distinguished from technology as the development of knowledge is distinguished from its application in the service of getting jobs done more efficiently or with less menial labour. The practical character of decisions about whether or not to proceed with a particular technological application - such as the building of nuclear power plants - is very much a part of this emphasis.

The Scientific Skill Development emphasis has science subject matter taught in the service of developing sophisticated conceptual and manipulative skills, such as observing, measuring, experimenting, hypothesizing, etc. It represents an emphasis on the means of scientific inquiry.

The Correct Explanations emphasis focusses heavily on the ends of scientific inquiry, rather than the means. The emphasis is familiar to anyone engaged in science teaching as the "master now, question later" strategy. (This is one emphasis in which no explicit communication is provided to the student about the purpose for learning science. The message is communicated by default, as it were. It says "Learn it because it's correct.")

The Self as Explainer emphasis concentrates on the similarities between a student's explanatory activities within his/her cultural context, and the explanatory ideas of scientists within their own cultural matrix. Thus the development of scientific ideas shows up as a function of human purpose, and it is only a short step from there to looking at other modes of explanation, such as religion and magic, to see that a different kind of human purpose is served by those. (Incidentally, it is within this curriculum emphasis that the perplexing educational problems arising from the creation/evolution controversy can be explored and dealt with most fruitfully.)

The Solid Foundation emphasis answers the student query about the purpose of learning "this stuff" in a straightforward manner: "to get ready for the 'stuff' you are going to learn next year." In some ways this is a reassuring curriculum emphasis, for it indicates to the student that he/she is learning something that fits into a structure which has been thought about and planned. This is the familiar curriculum emphasis which invites secondary school teachers to tell elementary school teachers what they should teach, and in turn invites university professors to tell secondary school teachers what they should teach, graduate schools to tell under-graduate instructors what they should teach, etc. (This is another emphasis whose message is communicated by default.)

Is "scientific literacy" a curriculum emphasis for science education? No. The seven curriculum emphases listed above are relatively distinct, but scientific literacy has a variety of definitions. In some current Canadian examples of usage, for instance, we find the following discrepancies. Page's discussion paper suggests that scientific literacy represents a Science, Technology and Decisions curriculum emphasis with examples drawn heavily from the Canadian context.³ Yet the British Columbia Science Assessment definition casts scientific literacy more like a Structure of Science emphasis,⁴ and Newfoundland's 1978 curriculum guideline for elementary science suggests a blend of parts of three emphases (Solid Foundation, Scientific Skill Development and Everyday Coping). Similarly,

the large bulk of published information in the science education literature shows that different authors define scientific literacy as different combinations, in whole or in part, of the curriculum emphases I have listed. I will have more to say about this eclecticism in chapter 4.

How Do Curriculum Emphases Get Into Programs?

Curriculum emphases go in and out of fashion. Economic, cultural and nationalistic factors are among those determining which emphases are present in the school science program at any given time. The emphases are selected, then, and the process by which the selection occurs is a political one. Thus it is not the case that there are some "correct" emphases and other "wrong" ones. Each is a legitimate candidate for choice.

A further point is worth noting about the making of policy choices concerning curriculum emphases. A curriculum emphasis does not necessarily have to control the science education orientation for a child's entire school career, or even for a period as long as one year. Technically speaking, a curriculum emphasis can be made to "materialize" in a learner's experience in the course of teaching about five to six weeks' worth of science subject matter (roughly what is referred to as an instructional "unit"). That is, there is a minimum of time which an emphasis requires to be developed, but a given program for a school year could incorporate several emphases in sequence (though, by definition, not simultaneously).⁵

III SCIENTIFIC LITERACY: FIRST THE SLOGAN

In discussing goals of science education programs, many professionals now use the term "scientific literacy" to represent comprehensive, balanced and composite goal statements which cover all curriculum emphases for science education. That is, in the usage of such people, "scientific literacy" is not a narrow or specific kind of goal, on the order of a single curriculum emphasis. Yet, as we have seen in the three examples of Canadian usage just cited, there is some promiscuity of usage about the term. Different people mean different things when they use it.

How could this have come about? Easily. Promiscuity of usage is a characteristic of educational slogans which have been around for a while. It is therefore worth a detailed examination of the history of the phrase "scientific literacy" - for it began its linguistic life in science education as a slogan rather than as a definition.

Scientific Literacy and US National Manpower

Let us consider briefly what educational slogans are all about, especially as they contrast with educational definitions, and also examine an early use of "scientific literacy" in the United States (where the phrase seems to have originated in the 1950s) to reveal its slogan-like features. Two analytical treatments of slogans will be helpful, the one by Israel Scheffler¹ and the other by Paul Komisar and James McClellan.²

We begin with Scheffler: "Slogans in education provide rallying symbols of key ideas and attitudes of educational movements."³ Whereas

educational definitions serve the community by providing clarification and facilitating communication, slogans serve by "attracting new adherents and providing reassurance and strength to veterans."⁴ (This is a perfectly acceptable function of language, of course, especially in policy debate.)

Notice how one of the earliest (1960) published uses in the United States of the phrase "scientific literacy" occurs, in the volume Policies for Science Education produced by the Science Manpower Project at Teachers College, Columbia University.⁵ (That project drew much of its support from a group of 36 major American industries and foundations.) Reference to "scientific literacy" is made three times in the book - twice in the first chapter, written by the editor (Frederick Fitzpatrick, then Head of the Department of Teaching of Science at Teachers College, Columbia). Commenting on the extensive concentration of the group discussions on the need for scientific and technical manpower and the role science education plays in producing that manpower, Fitzpatrick cautions:

"...We should not lose sight of the fact that no citizen, whether or not he is engaged in scientific endeavors, can be literate in the modern sense until he has understanding and appreciation of science and its work... . If the Zeitgeist is to be favorable to the scientific enterprise, including both academic and industrial programs, the public must possess some degree of scientific literacy, at least enough to appreciate the general nature of scientific endeavor and its potential contributions to a better way of life."⁶

Fitzpatrick is here using "scientific literacy" as a rallying symbol for an educational ideology, not as a definition. The general meaning of the phrase is fairly clear, if we do not ask too many specific questions. The function of the statement, though, is to gain adherents to the idea that too much attention to one goal for science education programs (the production of scientific and technical manpower) would be penny-wise and pound-foolish, since the citizenry has to pay taxes to support the work and training of those people. Thus the citizenry had better be sympathetic:

"If our young people are to possess any marked degree of scientific literacy they must exert themselves... . We need a public attitude which makes ignorance unfashionable and holds the acquisition of knowledge in esteem."7

The point is hammered home later in the book in the only other reference to scientific literacy. (This one was not written by Fitzpatrick.)

"The ultimate fate of the scientific enterprise is in no small degree dependent upon establishing a species of scientific literacy in the general population."8

The Logic of Educational Slogans

Let us shift focus to Komisar and McClellan now, and concentrate on another feature of slogans which is worthy of our attention - their logical construction. Because slogans most closely resemble generalizations in their logical features, Komisar and McClellan point out, it is perfectly natural to expect that one can unerringly draw implications from a slogan to one's particular situation. In the present case, then, we would expect simply to deduce from "scientific literacy" the particulars which the generalization-like statement would be assumed to summarize. But notice, in our example above, that Fitzpatrick did not specify particulars A, B, C, D and E, and then summarize them with the generalization "Scientific literacy is important." Instead, he simply used the phrase with a meaning that is more or less suggestive of some particulars but is actually very general and shadowy. To ask "How would a scientifically literate student behave, or think, or make decisions?" would be to invite different individuals to interpret the slogan in their own ways. Komisar and McClellan put it this way:

"Seeking to find the particulars summarized by a slogan is logically a quite different kind of procedure from that of finding the particular implications of a generalization. Between the generalized slogan and its application to a particular case stands a somewhat arbitrary act of interpretation."9

Consistent with this logical feature, slogans have to be deliberately restricted or interpreted.

"Some person or group actually makes this slogan mean this or that kind of educational program. They give the slogan this interpretation. In a sense, they are legislating or establishing a rule for the interpretation of their slogan."¹⁰ (Emphases are in the original.)

It follows that there can be no "correct" interpretation of a slogan, since the logic of translation from slogan to program is not bound by the rules of logical deduction, but is only guided by some sense of reasonable consistency. That is in the nature of slogans; it is not my intention to suggest that interpreters use linguistic legerdemain or sloppy logic.

We can see the Fitzpatrick statement, then, as a watershed. I am not claiming that Fitzpatrick invented the slogan, only that the way he used it in a prestigious document probably crystallized what was already "in the air." Indeed, an earlier use of the phrase appears, for example, in a paper published by Paul Hurd in 1958.¹¹ Again, in 1960 Alan Waterman, then Director of the National Science Foundation, used the phrase in much the way Fitzpatrick did. Waterman made relatively brief reference to NSF's concern that it was "urgent that the level of scientific literacy on the part of the general public be markedly raised" so that the citizenry would have "at least a general knowledge and understanding of the nature of science and its implications for the national defense and welfare." This, because "progress in science depends to a considerable extent on public understanding and support."¹² It was Fitzpatrick, though, who coined the rallying symbol for an educational ideology based on scientific literacy for the general public in an influential document speaking directly to a US national priority of the 1950s. The logic of slogans being what it is, somewhat arbitrary interpretations would have to be part of any attempt to convert "scientific literacy" into statements of aims for science education programs. Accordingly, a diversity of interpretations is to be expected in the science education literature published in the US which, given the cultural diffusion that is part of any profession, has inevitably filtered

into Canadian discourse (and the discourse of other countries as well, obviously).

Let us turn next to an examination of the diversity of interpretations given to "scientific literacy" between about 1960 and about 1980.

IV THE MANY FACES OF SCIENTIFIC LITERACY

The better part of a decade passed between the publication of Fitzpatrick's rallying call for scientific literacy and the appearance of Paul Hurd's definitive work on secondary school science curriculum in the United States.¹ By 1969 much had been written about scientific literacy; Hurd, commenting on the scene, characterized it as follows:

"No one seems to deny that developing a scientific literacy is an essential component of general education, although there is little agreement as to just what this means. One idea does seem quite clear: the role of science in our culture, its integration into nearly every aspect of human life and human needs, demands a revamping of science teaching to develop a coherence of science and society. The present curriculum reform has resulted in courses that are bound to scientific disciplines neglecting the social aspects of science."²

Anyone familiar with the so-called "alphabet courses" (or "ABC courses") - BSCS, CHEMS, PSSC* etc. - developed during that period in the United States (and widely adopted in Canada) will know that Hurd's characterization is accurate. What seems to have happened is that new courses were developed for the pool of potential scientific and technical manpower first, but that (with very few exceptions, at least among the secondary school courses) the "general public" Fitzpatrick referred to was not very well served by the science course reforms. Apparently, the scientific literacy of the general public was not a top priority of curriculum

* Biological Sciences Curriculum Study, Chemical Education Material Study, Physical Science Study Committee.

reformers. The reading demand, conceptual level and curriculum emphasis of the alphabet courses (with the possible exception of some BSCS efforts) simply did not operationalize the ideology Fitzpatrick had announced.

To be sure, there were many interpretations of scientific literacy (as Hurd suggests). In this section I should like to make some sense of all that interpretive activity, by calling attention to its development in two directions. Some writers attempted to comment on the spate of interpretations by combining them, thus producing a composite sense of scientific literacy. Others retained a distinctive sense of the concept, one which would grow and take on more meaning when classroom research and student evaluation were based on it.

The Composite Sense of Scientific Literacy

The most exhaustive composite definition of scientific literacy to appear in the science education literature to date is the "theoretical model of scientific literacy" which Lawrence Gabel developed in 1976 as part of his doctoral thesis.³ From a very large and complete data base, Gabel collected statements which were interpretations of the meaning of scientific literacy, and ultimately produced a "model" in which all of the statements he found could be categorized. His model has the following eight "dimensions," each of which refers to an aspect of science education which someone has referred to in the process of interpreting the meaning of scientific literacy:

- I. Organization of Knowledge
- II. Intellectual Processes
- III. Values and Ethics
- IV. Process of Inquiry
- V. Human Endeavour
- VI. Interaction of Science and Technology

VII. Interaction of Science and Society

VIII. Interaction of Science, Technology and Society

Bear in mind that the interpretive statements Gabel was categorizing had been suggested as statements of educational aims, for the most part; hence he needed a second dimension to the "model." For that he combined the six major categories for cognitive objectives (Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation) in the widely used taxonomy developed by Bloom and others⁴ with their three major categories for affective objectives (Valuing, Behaving and Advocating).⁵ Thus the "model" is a grid consisting of eight categories on one dimension and nine on the other. Gabel reports that from the literature he was able to find entries for all but 16 of the 72 cells. To complete the composite picture, Gabel himself generated statements which would fill the remaining 16.⁶ (See Table 1.)

What is immediately striking about Gabel's model is that it includes, under the definition of scientific literacy, every conceivable category of science education objectives. Table 2 has been prepared to make the point visibly. There, my seven curriculum emphases for science education, based on a historical analysis of practice, are compared to Gabel's eight categories. The reader will quickly see that Gabel's categories do not differ significantly from the seven major categories of science education aims I identified. To further illustrate the comprehensiveness of Gabel's "model," I have included in Table 2 the results of two major historical surveys of the objectives for chemistry and biology teaching as they have appeared in the US professional literature on science education from 1918 through 1972. The chemistry study shows nine major categories,⁷ and the biology study shows seven.⁸ Once again, Gabel's categories do not differ significantly.

Thus, scientific literacy has had so many interpretations that it now means virtually everything to do with science education. At least someone

Table 1: Dimensions of Gabel's Composite View of Scientific Literacy (after Gabel, p. 93).
(x = not found among the interpretations in the literature)

Dimensions of Scientific Literacy	Major Categories of Cognitive Objectives						Major Categories of Affective Objectives		
	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation	Valuing	Behaving	Advocating
I Organization of Knowledge (a) Facts (b) Generalizations (c) Disciplines				x	x	x	x	x	
II Intellectual Processes									
III Values and Ethics					x				
IV Process of Inquiry			x				x	x	x
V Human Endeavour							x		
VI Interaction of Science and Technology							x	x	x
VII Interaction of Science and Society								x	
VIII Interaction of Science, Technology and Society									

Table 2: The Comprehensiveness of Gabel's Composite View of Scientific Literacy

Roberts: 7 Curriculum Emphases for Science Education, 1900-present	Gabel: 8 Dimensions of Scientific Literacy, 1957-1976	Ogden: 9 Major Categories of Chemistry Objectives, 1918-1972	Ogden & Jackson: 7 Major Categories of Biology Objectives, 1918-1972
I Correct Explanations	I Organization of Knowledge	I Specific Topics in Chemistry	I Specific Topics in Biology
		II Scientific Methods of Thinking (skill and willingness)	II Scientific Methods of Thinking
		III Scientific Habits or Attitudes	
II Solid Foundation		IV Major Facts, Principles, or Fundamentals	III Major Facts, Principles, Concepts or Fundamentals
		V Career Development	IV Career Development
III Structure of Science	IV Process of Inquiry	VI Nature of Science and Scientists	
IV Scientific Skill Development	II Intellectual Processes	VII Processes, Skills and Techniques of Inquiry	V Processes, Skills and Techniques of Inquiry
V Self as Explainer	III Values and Ethics		VI Interest and Hobby Development
	V Human Endeavour		
VI Everyday Coping	VI Interaction of Science and Technology	VIII Applications of Chemistry to Daily Life	VII Applications of Biology to Daily Life
VII Science, Technology and Decisions	VII Interaction of Science and Society	IX Sociological Implications	
	VIII Interaction of Science, Technology and Society		

has an interpretation for scientific literacy which will fit into, or spread across some combination of, all the major categories of science education aims and objectives which have ever appeared.

Evolution of the Composite Sense of Scientific Literacy

Let us interpret the growth of the composite sense of scientific literacy by recalling that educational slogans (a) serve as rallying symbols for an ideology, and (b) have to be interpreted. As a slogan, scientific literacy seems to have a five-part developmental history which is consistent with these two features and which looks more or less like the following:

(1) Fitzpatrick crystallized an ideology that was already "in the air" and made an emphatic statement about it in a prestigious document published in 1960. I must say I was surprised to find no mention of scientific literacy in the equally prestigious 59th Yearbook of the (US) National Society for the Study of Education, Rethinking Science Education, which also appeared in 1960.⁹ (Its authors do, however, express sentiments analogous to those underlying the concept of scientific literacy.) I have marked the Fitzpatrick statement as the first significant use of the phrase "scientific literacy". Others, for reasons not clear to me, credit Herbert Bailey with inventing the phrase in a paper which appeared in Saturday Review in 1957.¹⁰ Yet Bailey, then Director of Princeton University Press, was not writing about science education and did not use the phrase "scientific literacy" at all. He was calling attention to the number of books being produced by university presses in the US about science which in his judgement could be understood by intelligent nonscientists. (The editor made a comment that the university presses "are helping the citizens of a scientific era to remain literate." Perhaps that is the connection.)

We can call this early period of our slogan's development, from about 1957 to 1963, its period of legitimation. During that time arguments were advanced promoting aspects of the ideology associated with scientific literacy. And, inevitably, some interpretations were made about the implications of the new slogan for program development.¹¹

(2) A period of more serious interpretation followed, from about 1963 to 1966. This is not to suggest that earlier interpretations were frivolous, but rather that the intention of the writers in this next period seems to be different. Recall that the interpretation of a slogan involves a deliberate act of choice (not a logical deduction from general to particular); hence, there are no criteria for knowing whose interpretation is correct. Multiple meanings of equivalent legitimacy are to be expected. In the case of scientific literacy, Robert Carleton certainly documented the fact that multiple meanings were abroad in the land when, in 1963, he published without comment the interpretations of twelve prominent scientists and science educators who responded to his question, "What does it mean to be scientifically literate?" (Carleton was, at that time, Executive Secretary of the National Science Teachers Association in the US, an organization with obvious practical interest in the interpretation of the slogan.) The twelve interpretations are richly diverse.¹²

One finds some systematic research in this period as well. For example, one interpretation of scientific literacy had to do with the reading of "lay" articles about science in common magazines and newspapers. Several studies were conducted about the reading demand and conceptual load of such articles.¹³

(3) As the interpretations of scientific literacy continued, and continued to be diverse, it seems in retrospect to have been inevitable that someone would attempt an initial consolidation. It was Milton Pella and his colleagues in the Scientific Literacy Center at the University of Wisconsin in Madison who did so. In 1966 the classic "Referents to Scientific Literacy" was published as the result of a complex and comprehensive literature analysis.¹⁴ That study presupposed that the definition of scientific literacy would be composite. The investigators identified the universe of interpretations for the term by searching literature on the basis of nine index terms which were already composite, but which were also consistent with early connotations of the slogan itself. It is instructive to see what the terms were:

- . scientific literacy
- . science and/or technology and the citizen
- . relationships or interrelationships of science and/or technology and society and social problems
- . relationship of science and technology
- . science and/or technology and culture
- . relationship between scientists and nonscientists
- . science and the public domain
- . science and general education
- . the scientific and/or technological revolution

By an elaborate selection procedure, the investigators identified 100 papers and subsequently analyzed them for the "referents" authors made to scientific literacy. The result was, of course, a composite picture:

"The scientifically literate individual presently is characterized as one with an understanding of the

- basic concepts in science
- nature of science
- ethics that control the scientist in his work
- interrelationships of science and society
- interrelationships of science and the humanities
- differences between science and technology."15

The investigators' concluding comment was that three of the six dimensions seemed to be more important than the other three: interrelationships of science and society, ethics of science and nature of science ranked as the more important, given the number of referents in the literature examined.

(4) There ensued a period of further interpretation, of more diversity. Eight years after the publication of "Referents," Michael Agin expressed concern as follows:

"Many individuals use the term 'scientific literacy' but fail to give it an adequate meaning; they assume that everyone knows what the concept means. There is, therefore, a need for a more specific definition or description of the concept so that better communication is possible. A frame of reference should be established to help consolidate and summarize the many definitions."¹⁶

Again based his own paper on Pella's categories, so he surely cannot be saying that no "frame of reference" exists which can "consolidate and summarize the many definitions." Instead, he seems to be concerned that Pella's consolidation did not stop further interpretations. But, of course, that is what we expect from a slogan and, indeed, that eight-year period (1966-1974) was quite an active one for individuals writing about scientific literacy.¹⁷ (Not surprisingly, people are still writing about it.)¹⁸ Agin organized a symposium on scientific literacy at the 1975 meeting of the National Association for Research in Science Teaching in Los Angeles.¹⁹ Pella's paper oriented scientific literacy in a general framework of literacy,²⁰ and O'Hearn used the Pella framework as a springboard for examining "future education" based on science.²¹ In a paper completed about a year later, Dede reflected on the symposium, especially O'Hearn's paper, in the specific context of university courses on science and society.²² Interpretation, then, did not stop during this period, but considerable interest was expressed, particularly during the 1975 symposium, that "models" (definitions, I presume) should be clarified, when speaking of scientific literacy.

(5) Eventually the interpretations of the slogan reached a point where very little could be said that was new. We might say the slogan reached a point of maturity or, perhaps, exhaustion. Gabel's consolidation shows that by 1976 scientific literacy had come to be equated with virtually all of the goals of school science programs for all students. Indeed, we find precisely that equation used in the introduction to the US National Assessment of Science report for 1976-77:

"As a result of National Assessment's experience in the development of science achievement measures over the past 10 years, and the suggestions

made in the most recent development cycle, the 1976-77 science assessment is an extremely comprehensive measure of the scientific literacy of young Americans."²³

Thus did scientific literacy come to be an umbrella concept to signify comprehensiveness in the purposes of science teaching in the schools.

Two Distinctive Senses of Scientific Literacy

The composite sense of scientific literacy encompasses all goals (historically speaking) of school science programs, as we have seen, and indeed it suggests that all of those are appropriate in some measure for all students. But the "maturity" of the slogan does not mean that it now has a consistent definition wherever it is used. Scientific literacy is still a slogan, even though the ideology it now represents is that of comprehensiveness rather than the original nontechnical connotation of Fitzpatrick. Any serious definition for the phrase still has to be stipulated. More discussion of that point will be important in the concluding section of this paper, but at this point it is helpful in foreshadowing that discussion to consider two distinctive and well-defined senses of scientific literacy, the one by Robert Karplus and the other by Leopold Klopfer.

In 1964, Karplus set down one of the clearest definitions we have for scientific literacy, one which could then be used to guide program development and student evaluation in the Science Curriculum Improvement Study (SCIS) for elementary schools. Here is the way he put it:

"The Science Curriculum Improvement Study is ... attempting to develop a teaching program of which the objective is the increase of scientific literacy in the school and adult populations."²⁴

Scientific literacy is defined somewhat later in the paper, in the following way:

"In other words, to be able to use information obtained by others, to benefit from the reading of textbooks and other references, the individual must have a conceptual structure and a means of communication that

enable him to interpret the information as though he had obtained it himself. I shall call this functional understanding of science concepts 'scientific literacy.' It should be the principal objective of the elementary school science program."²⁵

The distinctive sense of Karplus's definition (which is certainly not composite) was embodied in a teaching program, and his interpretation of scientific literacy has not changed.²⁶

Such is the difference between definitions and slogans in education. Materials development and teaching need crisp definitions to guide them, not slogans. Let us examine briefly a major study of the effectiveness of SCIS reported by Bowyer and Linr.²⁷ (There have been many other studies of SCIS, of course.) Having found a school system which used the SCIS program in all six grades of elementary school, and a population of nearly 200 students who had been exposed to the program from grade 1 right through grade 6, the investigators operationalized the original sense of scientific literacy built into the materials and tested the students, with some interesting results (especially gender effects). Most important for our purposes, though, the investigators are careful to point out that the SCIS definition of scientific literacy "refers to the first of the definitional components identified by Pella: knowledge of basic concepts in science and an understanding of the nature of science."²⁸ No effort was made, either by the investigators or the program they tested, to be comprehensive about scientific literacy, as Pella had been.

It would not have been possible to develop this coherent line of materials development and research, from which practice can be linked to more or less predictable results, without a clear, focussed definition of scientific literacy. A curriculum policy committee might find the accumulated research information about the SCIS program a very helpful bit of data in their deliberations. The information would tell them that "improving scientific literacy" is possible - and "possibles" are important considerations in policy discussion. "Just use this program," the research tells them, "and you can do the job" (to such-and-such a degree, with

thus-and-so kinds of children and teachers - the inevitable qualifications appended to claims made on the basis of educational research). But it is the Karplus kind of scientific literacy which is being improved, not the composite kind. Perhaps the point is obvious, but there is a legacy of confusion associated with any educational slogan: the same term refers to various sets of educational aims which, when operationalized, look different in practice and in results.

The second distinctive sense of scientific literacy I wish to remark upon is that which Leopold Klopfer used in an interesting programmatic piece titled "Science Education in 1991."²⁹ The "basic dilemma" of science education will be resolved by streaming, says Klopfer. That dilemma is the distinction between preprofessional science education (for "scientists, engineers, and physicians") and science education for the "90 percent of all working people ... engaged in occupations that are not directly related to science."³⁰ Klopfer's point is very much like the one Fitzpatrick made in 1960: the citizenry in general needs a science education which looks quite different from that of the student identified as a pre-professional in a scientific or technical field.

"The key feature in the science education pattern in 1991 will be the clear distinction of two curricular streams through the secondary schools and colleges. One curricular stream will be designed for students planning to enter careers as scientists, physicians, and engineers. We shall call this the Prospective Scientists stream, or PS stream. The other curricular stream will be designed for students who will become the nonscientist citizenry ... housewives, service workers, salesmen, ...etc. We shall call this the Scientific Literacy stream, or SL stream. Differentiation of students ... will begin at about age fourteen when they choose the high school they will attend."³¹

Klopfer goes on, then, to describe in a convincing way the practical features of some fairly rigorous teaching in the two streams; despite its equivalent rigor, the teaching in the two streams is quite different, as one would expect.

So far as one can tell from the program features, Klopfer's distinctive sense of scientific literacy resembles a combination of four of my curriculum emphases: Everyday Coping; Science, Technology and Decisions; Self as Explainer; and Structure of Science. The Prospective Scientists program, similarly examined, seems to show four also (but a different four): Correct Explanations, Scientific Skill Development, Solid Foundation, and Structure of Science. The importance of Klopfer's use of "scientific literacy" in this way is that it enables us to envision major activities of two separate but equally legitimate teaching programs. It recalls for us the conceptual tension inherent in Fitzpatrick's original statement, and reminds us once again that different students may find different kinds of programs appropriate. Scientific literacy in its composite sense might be a thoroughly comprehensive universe from which to select curriculum emphases to suit the needs of different groups of students, but the composite sense is not too useful to a curriculum policy committee trying to think through legitimate program differentiation.

V THE MIXED BLESSINGS OF AN AGING SLOGAN

Those who favour a composite sense of scientific literacy, when speaking of the broad overall goals of school science programs, are essentially arguing that science is multifaceted and that it is important for students to be exposed to each of those facets, in some measure, in their science education. In the practical context of policy debate, however, it is probably inevitable that different speakers will have different meanings for the phrase "scientific literacy," both partially composite meanings and distinctive meanings. Any speaker can point to the science education literature on this topic, of which we see a fair sample in the present paper, and find someone who has already used "scientific literacy" in his or her selected way. Such varied use is to be expected of a fairly mature slogan, as a matter of course.

Nevertheless, the point all of us need to remember is that when different individuals attach different meanings to a phrase, they are indicating that there is something different about their values. The unfortunate legacy of the phrase "scientific literacy" is that, used by different speakers, it can mask legitimate and important differences in value preferences concerning the goals of science education.

Against that, the fortunate legacy of "scientific literacy" is that those who argue for it and do research on it frequently point out that a kind of sterility attaches to science teaching if it is oriented strictly to what I would call the Solid Foundation and Correct Explanation emphases. These authors argue that science education programs need to focus on

those facets of science which penetrate the practical affairs of individual students, citizens and nations. They seek a perspective on science which sees it as more than a *Ding an sich*, and they seek to have that perspective taught in schools, especially to the large majority of students who will never become scientists.

It is also my own position that balance is extremely important in the goals set for school science programs. The rationale for that statement lies in the equal legitimacy of the several fields of human endeavour which science touches upon, both in practical affairs and in academic fields of study. Thus, for example, the Correct Explanations, Solid Foundation and Scientific Skill Development emphases draw on the sciences themselves as parent disciplines. But Structure of Science draws on the philosophy of science; Everyday Coping draws on engineering; Science, Technology and Decisions has its roots partly in engineering, partly in various technical and practical arts, and partly in decision making, political science and practical philosophy. Again, the Self as Explainer emphasis draws on the interpretive activity that characterizes some approaches to the history and philosophy of science. What makes any one of these more appropriate than another in the school curriculum? Granted, larger doses of some emphases are more appropriate for some students (Klopfer's point). But in the main, it is difficult to avoid the conclusion that balance is important for all students.

Finally, I have three suggestions concerning curriculum policy debate itself, from the perspective of scientific literacy.

- (1) Policy debate about aims for school science programs would do well to keep scientific literacy in the background as an ideal of balance, but air value positions by using a crisper set of terms - terms that express the different values which different senses of the phrase "scientific literacy" actually mask. (Curriculum Emphases, or Gabel's "dimensions," or Pella's "categories" - or

other equally discriminating sets of terms - would be more helpful.)

- (2) There is an unfortunate tendency in the history of policy debate about science education to stage massive crusades in favour of single curriculum emphases. Such crusades have frequently taken the form "Start doing X and stop doing Y!" They represent a notoriously wasteful approach to the multifaceted deliberation process which public confidence in curriculum making requires in a democracy.
- (3) The problems of implementing policy changes are bound to enter policy debates of this sort. Single-mindedness about one or two curriculum emphases is sometimes justified on the grounds of implementation difficulties or problems with the "delivery system." Textbooks, for example, usually reflect a single curriculum emphasis but are designed for an entire year of instruction. Thus a set of textbooks or science series can lock an entire elementary school program into a single emphasis. Again, teachers are frequently educated in specific emphases; these vary primarily according to the period of history when the teacher's education took place, sometimes the country or region where it occurred, etc. These are very real considerations for a policy committee. But the challenge of implementation and the challenge of setting defensible goals need to be kept separate. The former is strictly a professional responsibility, while the latter is both a professional and a public matter.

The blessings of the aging slogan "scientific literacy" are indeed mixed. Nevertheless, with care a curriculum policy committee can capitalize on the best features of a significant strain of thought in the history of science education and can translate those features into an educational legacy that will stand proudly. Armed with an overall goals

concept of scientific literacy, and giving attention to its several facets, a committee can take on the challenges of the five discussion papers with which the present paper began, and can do all of them justice.

NOTES

I. Introduction

1. James E. Page, A Canadian Context for Science Education, Science Council of Canada, Ottawa, October 1979.
2. Glen S. Aikenhead, Science in Social Issues: Implications for Teaching, Science Council of Canada, Ottawa, December 1980.
3. Donald A. George, An Engineer's View of Science Education, Science Council of Canada, Ottawa, June 1981.
4. Hugh Munby, What is Scientific Thinking?, Science Council of Canada, Ottawa, March 1982.
5. Marcel Risi, Macroscopie: A Holistic Approach to Science Teaching, Science Council of Canada, October 1982.

II. Curriculum Emphases: Objects of Choice

1. While this instance is hypothetical, a real example showing very similar distinctions appears in G. Orpwood and D. Roberts, "Curriculum Emphases in Science Education III: The Analysis of Textbooks," The Crucible, vol. 11, May 1980, pp. 36-39.
2. For more elaboration, see Douglas A. Roberts, "Developing the Concept of 'Curriculum Emphases' in Science Education," Science Education, vol. 66, no. 2, 1982, pp. 243-260.
3. James E. Page, op. cit.
4. See E.D. Hobbs and Gaalen L. Erickson, "Results of the 1978 British Columbia Science Assessment," Canadian Journal of Education, vol. 5, no. 4, 1980, pp. 63-80.
5. A set of alternative teacher's manuals showing how the same science unit can reveal three different curriculum emphases has been developed. See

Douglas A. Roberts and Graham W.F. Orpwood, Properties of Matter: A Teacher's Guide to Alternative Versions, OISE Press, Toronto, 1979.

III. Scientific Literacy: First the Slogan

1. In Israel Scheffler, The Language of Education, Charles C. Thomas, Springfield, Illinois, 1965.
2. B. Paul Komisar and James E. McClellan, "The Logic of Slogans," in Language and Concepts in Education, ed. B. Othanel Smith and Robert H. Ennis, Rand McNally and Company, Chicago, 1961, pp. 195-214.
3. Scheffler, op. cit., p. 36.
4. Ibid.
5. Frederick L. Fitzpatrick, ed., Policies for Science Education, Teachers College, Columbia University, New York, 1960.
6. Ibid., p. 6.
7. Ibid., p. 18.
8. Ibid., p. 169.
9. Komisar and McClellan, op. cit., p. 200.
10. Ibid., pp. 201-202.
11. Paul DeHart Hurd, "Science Literacy: Its Meaning for American Schools," Educational Leadership, vol. 16, no. 1, 1958, pp. 13-16 and 52.
12. Alan T. Waterman, "National Science Foundation: A Ten-Year Resumé," Science, vol. 131, no. 3410, 6 May 1960, pp. 1341-1354 (specifically p. 1349).

IV. The Many Faces of Scientific Literacy

1. Paul DeHart Hurd, New Directions in Teaching Secondary School Science, Rand McNally and Company, Chicago, 1969.
2. Ibid., pp. 108-109.
3. Lawrence Lee Gabel, "The Development of a Model to Determine Perceptions of Scientific Literacy," PhD Thesis, The Ohio State University, Columbus, Ohio, 1976.
4. Benjamin S. Bloom, ed., Taxonomy of Educational Objectives: The Classification of Educational Goals, Handbook 1: Cognitive Domain, David McKay Co., Inc., New York, 1956.

5. David R. Krathwohl, Benjamin S. Bloom and Bertram B. Masia, Taxonomy of Educational Objectives: The Classification of Educational Goals, Handbook II. Affective Domain, David McKay Co., Inc., 1964.

6. Gabel, op. cit., p. 92.

7. William R. Ogden, "Secondary School Chemistry Teaching, 1918-1972: Objectives as Stated in Periodical Literature," Journal of Research in Science Teaching, vol. 12, no. 3, 1975, pp. 235-246.

8. William R. Ogden and Janis L. Jackson, "Secondary School Biology Teaching, 1918-1972: Objectives as Stated in Periodical Literature," Science Education, vol. 62, no. 3, 1978, pp. 291-302.

9. Nelson B. Henry, ed., Rethinking Science Education: The 59th Yearbook of the National Society for the Study of Education, Part 1, The University of Chicago Press, Chicago, 1960.

10. Herbert S. Bailey, Jr., "How to Be Literate in a Scientific Age," The Saturday Review, vol. 40, May 4, 1957, pp. 13-15.

11. The following list is not intended to be exhaustive, but does illustrate that there was considerable activity.

- (a) John Behnke, "Scientific Literacy," AIBS Newsletter, vol. 10, no. 2, 1960, pp. 21-22.
- (b) Hubert Evans, "Toward Scientific Literacy," Teachers College Record, vol. 64, no. 1, 1962, pp. 74-79.
- (c) Philip G. Johnson, "The Goals of Science Education," Theory into Practice, vol. 1, no. 5, 1962, pp. 239-244.
- (d) Polykarp Kusch, "Educating for Scientific Literacy in Physics," School and Society, vol. 88, no. 2173, 1960, pp. 198-201.
- (e) Morris Shamos, "The Price of Scientific Literacy," National Association of Secondary School Principals Bulletin, vol. 47, no. 282, 1963, pp. 41-51.
- (f) Warren Weaver, "Science for Everybody," Saturday Review, vol. 45, 7 July 1962, pp. 45-46.
- (g) Alma S. Wittlin, "Scientific Literacy Begins in the Elementary School," Science Education, vol. 47, no. 4, 1963, pp. 331-342.

12. Robert H. Carleton, "On Scientific Literacy," NEA Journal, vol. 52, April 1963, pp. 33-35 and 57. Some other items of possible interest during 1963-1966 are these:

- (a) Nancy Barrett Hamilton, "The Scientific Literacy of Seniors in Urban, Suburban, and Rural High Schools in Kentucky," PhD Thesis, The Ohio State University, Columbus, Ohio, 1965.
- (b) Richard E. Haney, The Changing Curriculum: Science, Association for Supervision and Curriculum Development (NEA), Washington, DC, 1966.

- (c) Lloyd K. Johnson et al., Research in the Teaching of Science, 1965, US Department of Health, Education and Welfare Bulletin, 1965, no. 10, Washington DC (Supt. of Documents no. FS 5.229:29000-61), esp. pp. 142-145.
- (d) Merritt E. Kimball, "Opinions of Scientists and Science Teachers about Science," PhD Thesis, Stanford University, Palo Alto, California, 1965.

13. The following are pertinent:

- (a) Lazer Goldberg, "The Science Vocabulary in The New York Times and in Political Materials in 1960," EdD Thesis, Columbia University, New York, 1966.
- (b) Charles L. Koelsche and Ashley G. Morgan, "Scientific Literacy in the Sixties," University of Georgia Printing Office, Athens, Georgia, 1964, (ERIC accession no. ED 011 843).
- (c) Roger L. Wood, Milton O. Pella, and George T. O'Hearn, "Scientifically and/or Technologically Oriented Articles in Selected Newspapers," Journal of Research in Science Teaching, vol. 5, no. 2, 1967-68, pp. 151-153.

14. Milton O. Pella, George T. O'Hearn and Calvin W. Gale, "Referents to Scientific Literacy," Journal of Research in Science Teaching, vol. 4, no. 3, 1966, pp. 199-208.

15. Ibid., p. 206.

16. Michael L. Agin, "Education for Scientific Literacy: A Conceptual Frame of Reference and Some Applications," Science Education, vol. 58, no. 3, 1974, pp. 403-415 (specifically p. 405).

17. Again, this is not intended to be an exhaustive list, but is indicative of the activity of the period 1966-1974.

- (a) Ted F. Andrews, "Science Education for the Non-Scientist," Educational Technology, vol. 10, no. 1, 1970, pp. 29-32.
- (b) L.C. Comber and John P. Keeves, Science Education in Nineteen Countries, John Wiley & Sons, New York, 1973.
- (c) Donald R. Daugs, "Scientific Literacy - Re-examined," The Science Teacher, vol. 37, no. 8, 1970, pp. 10-11.
- (d) Thomas P. Evans, "Scientific Literacy: Whose Responsibility?", American Biology Teacher, vol. 32, no. 8, 1970, pp. 80-84.
- (e) William Jaffarian, "An Evaluation of the Relative Levels of Scientific Literacy Possessed by Twelfth Grade Students in Wisconsin," PhD Thesis, The University of Wisconsin, Madison, 1968.
- (f) Haskell Jones, "The Development of Certain Aspects of Scientific Literacy in College Freshmen Physical Science Students," PhD Thesis, The Ohio State University, Columbus, Ohio, 1969.

- (g) John B. Leake and Charles O. Hinerman, "Scientific Literacy and School Characteristics," School Science and Mathematics, vol. 73, no. 9, 1973, pp. 772-782.
- (h) Jerry P. Lightner, "Comment: The Cancer of Ignorance," Journal of Biological Education, vol. 8, October 1974, pp. 247-248.
- (i) W.T. Lippincott, "Editorially Speaking: The Citizen's Science," Journal of Chemical Education, vol. 48, December 1971, p. 781.
- (j) Peter Mason, "Speaking Scientific," Australian Science Teachers' Journal, vol. 17, October 1971, pp. 39-42.
- (k) National Science Teachers Association, Committee on Curriculum Studies, "School Science Education for the 70's," The Science Teacher, vol. 38, no. 8, 1971, pp. 46-51.
- (l) George T. O'Hearn, "Environmental Education: The New Scientific Literacy," National Association of Secondary School Principals Bulletin, vol. 56, no. 360, 1972, pp. 21-27.
- (m) Milton O. Pella, "Scientific Literacy and the High School Curriculum," School Science and Mathematics, vol. 67, no. 4, 1967, pp. 346-357.
- (n) Victor Showalter, "What Is Unified Science Education?: (Part 5) Program Objectives and Scientific Literacy," Prism II, Center for Unified Science Education, Columbus, Ohio, 1974.
- (o) Norman F. Smith, "The Challenge of Scientific Literacy," The Science Teacher, vol. 41, September 1974, pp. 34-35.
- (p) Manfield Stanley, "Literacy: The Crises of a Conventional Wisdom," School Review, vol. 80, no. 3, 1972, pp. 373-408.
- (q) Henry A. Teterin, "Scientific Literacy - Some Aspects of UNESCO'S Programme," Out-of-School Scientific and Technical Education, vol. 1, 1971, pp. 3-5.
- (r) Thomas M. Weiss, "The Spirit of Science," Science Education, vol. 53, no. 4, 1969, pp. 365-367.

18. A few of the interesting pieces published after 1974 are the following:

- (a) John R. Jungk, "Bio-Logical Dissection of Rhetorical flora," American Biology Teacher, vol. 39, no. 3, 1977, pp. 142-147 and 154.
- (b) Marcel C. LaFollette, "Conference Report: Humanistic Science Education in Japan and the United States," Science, Technology, and Human Values, vol. 4, no. 28, summer 1979, pp. 36-40 (ERIC accession no. ED 174 444).
- (c) Peter A. Rubba and Hans O. Andersen, "Development of an Instrument to Assess Secondary School Students' Understanding of the Nature of Scientific Knowledge," Science Education, vol. 62, no. 4, 1978, pp. 449-458.
- (d) John R. Tarp, "Toward Scientific Literacy for ALL our Students," The Science Teacher, vol. 45, no. 9, 1978, pp. 38-39.

19. Leopold E. Klopfer, "Scientific Literacy Reexamined," Science Education, vol. 60, no. 1, 1976, p. 95.

20. Milton O. Pella, "The Place or Function of Science for a Literate Citizenry," Science Education, vol. 60, no. 1, 1976, pp. 97-101.

21. George T. O'Hearn, "Science Literacy and Alternative Futures," Science Education, vol. 60, no. 1, 1976, pp. 103-114.

22. Christopher Dede, "Examining a Model for Teaching Scientific Literacy through Interdisciplinary Courses Focussed on Science-Related Issues," University of Houston at Clear Lake, Texas, 1976 (ERIC accession no. ED 123 129).

23. National Assessment of Educational Progress, "Science Achievement in the Schools: A Summary of Results from the 1976-77 National Assessment of Science," Education Commission of the States Science Report no. 08-S-01, December 1978, p. 1 (ERIC accession no. ED 164 337).

24. Robert Karplus, "The Science Curriculum Improvement Study," Journal of Research in Science Teaching, vol. 2, 1964, p. 293.

25. Ibid., p. 296.

26. An interesting reflective piece by Karplus, some years later, is "Science for Young Pupils," Prospects, vol. 8, no. 1, 1978, pp. 48-57.

27. Jane B. Bowyer and Marcia C. Linn, "Effectiveness of the Science Curriculum Improvement Study in Teaching Scientific Literacy," Journal of Research in Science Teaching, vol. 15, no. 3, 1978, pp. 209-219.

28. Ibid., p. 209.

29. Leopold E. Klopfer, "Science Education in 1991," School Review, vol. 77, nos. 3-4, 1969, pp. 199-217. Klopfer comments interestingly on scientific literacy in "Evaluation of Learning in Science," in B. Bloom, J.T. Hastings and G.F. Madaus, Handbook on Formative and Summative Evaluation of Student Learning, McGraw-Hill Book Co., Toronto, 1971, pp. 559-642.

30. Ibid., p. 201.

31. Ibid., pp. 203-204.

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